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DENUDATIONAL PROCESSES AND GEOMORPHIC CHARACTERISTICS OF THE KALIANI RIVER BASIN (ASSAM, INDIA)

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Abstract. Denudation relates to the removal of loosened material from a rock surface. This is carried out by wind or running water and exposes the underlying rock to further disintegration through the agents of erosion. Denudation is an external process and includes processes such as weathering, mass movement, transportation and erosion. In the long term, it ultimately leads to lowering of relief of the particular region where it is operating. Denudation is initiated by climatic factors and leads to specific geomorphic features in particular climatic regions. Thus the landform features formed in arid regions will differ from those in a humid region on a macro scale. However, some features may be common or almost similar to both regions on a micro scale e.g., mesa like features are common in some fluvial eroded landscapes as well as long as there are alternate bands of softer and harder rocks. Both endogenetic as well as exogenetic processes have played a crucial role in the character of landforms in the study area. The Kaliani River Basin (Diphu subdivision), Karbi Anglong district in Assam has been selected for identifying and studying the regions which are affected by denudation and the simultaneous geomorphic features formed. The basin is the result of past tectonic activity which has resulted in folding and faulting. Volcanic activity in the region has been known to occur in post Cretaceous times. The denudation processes in operation have imparted a unique geomorphic characteristic to the region giving it uneven and inaccessible terrain in some parts. The study area forms a part of the Karbi Anglong plateau comprising of a Precambrian platform. This feature has been significantly dissected and graded. An attempt has been made to study the geomorphic characteristics as a result of the denudational processes operating within the study area.

Keywords: denudation, erosion, mass wasting, base level, weathering

I. INTRODUCTION

Denudation is a continuous process and is found to operate on every part of the exposed surface of the Earth. The process leads to laying bare rock surfaces due to wasting and disintegration, and gradual reduction in relief of landforms. It is a completely natural process and depends upon agents such as wind chiefly

alongwith running water and ice in their respective areas where they are dominant in operation. The theory of structure, process and stage as proposed by W. M. Davis regarding landforms and the concept of cycle of erosion can be demonstrated through this process adequately. The landforms are reduced to almost flat land in a monocyclic operation. Interruptions during the stages of operation of denudational processes lead to a polycyclic order and land features develop which signify rejuvenation or upliftment of a particular region. Both the uplifting and downcutting action over the surface by earth movements and processes of mass wasting respectively are simultaneous phenomena. Thus river basins which have been uplifted through geologic times are also being gradually eroded towards their base levels gradually. The Kaliani (also referred to as Kalyani) River Basin, located in Karbi Anglong district Assam is a significant example of such an action.

The aim of the present study is:

1. To observe and investigate the denudational processes that are in operation in the chosen study area.
2. To identify the geomorphic features that have formed as a consequence.
3. To identify and mark those places within the basin which are prone to denudational processes, in three categories: severely, moderately or nominally.

II. THE STUDY AREA

The study area is located in northeast India, Assam between latitudes 26° 13' 47"N to 26° 40' 38" N and longitudes 93° 12' 38"E to 93° 48' 36"E (Fig. 1). It is located to the south of the Bramhaputra River and within the Mikir Hills and the Kaliani Reserve Forest zone which accounts for the rich biodiversity of the area. The area can be accessed through the town of Golaghat in the East and through the district headquarter at Diphu to the southeast. The region experiences tropical monsoon type of climate with occasional thunder squalls preceding the monsoon months (June - August) and temperatures ranging from 5° Celsius - 38° Celsius throughout the year. Winters are mild and foggy with scanty rainfall while summers are hot and sultry.

III.1. The physiography of the study area

The Kaliani River Basin is located at the northeastern extension of the peninsular landmass of the Indian subcontinent. The Kaliani River flows in a N –S and then SE - NE directions in the upper and lower parts of its basin respectively in the Kaliani Reserve Forest or the Chenghe Arnam plateau. The general slope of the basin is towards the east and the northeastern part, distinct geomorphic features have developed within the basin with an extensive floodplain which is adjacent to the floodplains of the Dhansiri, which is an older channel. The geomorphic features noticed are river terraces, slip off slopes, dykes and narrow banks in the middle and

lower part of the channel. It lies over a Precambrian plateau and has broad watersheds as vertical erosion has begun relatively in recent times. Thus, valley widening is more active due to a gneissic terrain and the first order nature of the streams. Since it is composed of hard rock cover dating back to Precambrian times, the channel experiences resistance while trying to attain base level with that of the Dhansiri River in the east. The depth of the channel does not exceed beyond a meter and hence is unable to contain the increased load of sediment and water during the monsoons collected at the headwaters of the tributary streams as well the trunk stream.

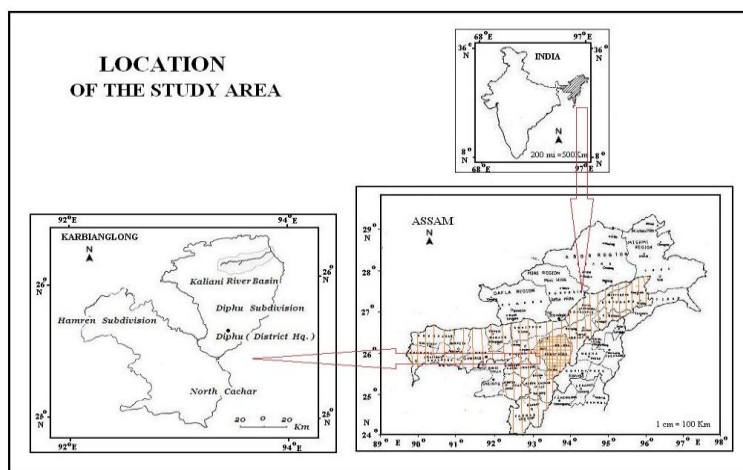


Fig. 1 Location of the Study Area

III.2. Brief geologic background

The Kaliani River Basin is a part of the Chenghe Arnam Plateau or the Mikir Hills situated to the north east of the Karbi Anglong district. It is composed of predominantly granite, gneiss and quartzite including patches of Sylhet Trap and few Tertiary formations. The geological character of the study area is the basis for rate of operation of denudational processes. The rate of operation of these processes ranging from mass wasting to mere degradation, is directly dependent upon the nature of regolith and rock masses. The materials are removed through rainwash, the flow of water in the tributary streams or the trunk channel. Loosened rockwaste moves down towards the trunk stream under the influence of gravity and is deposited in the channel bed. The almost shallow channel bed is unable to accommodate the excess water influx during the rainy season. This leads to flooding of the banks. The tertiary sedimentary rocks consisting of sandstones, limestones, ferruginous sandstones, interbedded with brown and gray shales, micaceous sandstones, quartzites, and pebbles in the lower reaches of the channel regime are all prone to easy

denudation. The physiographic subdivisions of the entire Kaliani River Basin can be arranged into four distinct zones on the basis of its geological character. This is necessary to identify the zones which can be categorized as severely, moderately or nominally denuded (Table 1).

Table 1. Physiographical and geological background of the Kaliani River Basin

Name of physical subdivision	Area (km ²)	Geological characteristics	Major relief and drainage features
1. The flat open expanse around the settlement of Kaja Kramcha.	35	Granite gneiss and quartz and quartzite with patches of Sylhet Trap overlain by an irregular bed of white clay.	The Kaliani River has its headwaters near Cheksa Parbat (593 m).The drainage here is of dendritic pattern. The terrain is flat, rocky and hard with scarps on both sides of the valley.
Moderately Denuded		The Barail series is found.	Highly folded and faulted structures with many sharp peaks.
2. The south western side on the right bank of the Kaliani River Basin.	437	Hard sandstone, grayish sandstone, carbonaceous shales are chiefly found. Highly folded strata pointing to the pushing of Gondwanaland along the Naga Thrust further south.	The valley of Sangri Langso is straight and the drainage in this region is particularly rectangular. The terrain has extensive ridges, flattened by the rivers which act as powerful agents of erosion carving out narrow v-shaped valleys.
Severely Denuded		The Jaintia series is found which gives coal and limestone overlain by the Surmas and is composed of coarse false bedded, ferruginous sandstone interbedded with shale, sandy shale, clay and conglomerate.	Rocks are less folded , a number of waterfalls are noted as well as hot springs .The terrain is intensely dissected by rivers and minor lineaments aligned W- E are noted .The land slopes down towards the R. Kaliani in the south and the R. Deopani in the north .
3. The northern side on the left bank of the Kaliani River Basin.	628		
Moderately Denuded			
4. The eastern part of the basin comprising the alluvial plains.	100	Quaternary deposits comprising of alluvium and laterites are found. Layers of thick new alluvium deposits.	Vast plains and marshy lands which are inundated during monsoons .Numerous oxbow lakes. These lands merge with the plains of Golaghat .The land slopes from the western to the eastern side.
Nominally Denuded			

III. 3. Operation of denudational processes

Denudation in this particular basin depends chiefly on moisture in the form of rainfall, running water or humid climatic conditions leading to decaying of rocks. The Kaliani River Basin is rugged and more elevated to the southern portion in comparison to the northern part. Thrusting from the southern part of the basin

during early Eocene led to uplifting of this region. The uplifted part became prone to degradation and the process of large scale downslope movement of loosened earth material became more prevalent. In present times loosened regolith found more upon the northern and eastern parts of the basin initiate the process of mass wasting more in these parts. Among the denudational processes, running water and mass - movement is noted chiefly (Fig. 2).



Fig. 2 Exposed rock outcrop near Kanaighat and pebbles and boulders exposed near Chowkiholes as a result of denudation and later removal of regolith through erosion.

Decomposed rock mantle when in prolonged contact with rain water easily loosens themselves along the slopes on the banks of the Barpung Langso and Tarapung Nadi to result in frequent landslides. Foliated rocks like slates and quartzites lead to steeply downward dipping slopes in some parts of the Kaliani River Basin.

Since the southern western part of the basin is elevated compared to the northern part, the southern part encounters the rain-bearing cloud foremost and hence receives more rainfall and is intensely dissected and steeper. The pounding action of the raindrops quickly disintegrates the soluble mineral salts in the rocks thereby making disintegration and denudation effective.

The Kaliani River Basin falls under moderate morphogenetic region and experiences maximum impact of fluvial erosion. It has undergone tectonic upheavals as a result of northwards drifting of the Gondwanaland and subsequently joining with the Eurasian landmass, repeatedly due to thrusting from southern portion of this river basin. The collision of the continental masses seems to have commenced around the Early Eocene about 40 – 50 million years before present (Dasgupta et al 2001) and thereby uplifting of the Shillong and Mikir Hill Plateaux have taken place after the Late Jurassic - Early Cretaceous.

Ruggedness of terrain has led to local climatic variations which determine the intensity of operation of various geomorphic processes. Besides the physical properties of the waste mantle as well as the nature of vegetal cover runoff characteristics also help to shape these landforms. The rainfall zones of the Kaliani

River Basin follow the alignment of the ridges and the scarps aligned south west to north east chiefly. The moisture laden winds which enter the Kaliani valley from the south west are obstructed by the waterdivide of the Nihang Langso, and they veer north east after shedding moisture on the windward side. Thus mostly dry winds enter the valley from the west and barring local pockets which receive some precipitation ranging from 50 cm - 150 cm.

The heaviest rainfall is received during the months of August and September with October being nearly dry, followed by minor showers during November and December. According to F. J. Monkhouse (1998) *"the term denudation is used widely to cover all the agents by which parts of the earth's surface are undergoing destruction, wastage and loss; the material thus removed is deposited elsewhere, to form sedimentary rocks"*. Thus, all regolith is the product of denudation. The study area has fine examples of denudational process initiated through running water. The nature of regolith in the region ranging from cobbles to fine alluvial is resulting. The deposits can be identified as: riverbed deposits, scree, residual soil, hillslope deposits and terrace deposits.

Riverbed deposits are found along the course of the Kaliani River only and its tributary channels. They are composed of light yellowish, grayish silty medium to coarse sands, gravels and cobbles and shingles mixed scattered to closely. The lower parts of the channel courses show deposits of brownish grey silty clay with rusty spots and brownish grey, fine silty sand which are non plastic and have a liquid limit of 55%. Thus, deposits ranging from cobbles to sand sized particles are noticed along the river channels.

Scree deposits are noted chiefly in the southern and north western part for the Kalyani River Basin. These comprise mainly of broken rock materials of different sizes and are found to accumulate at the base of scarps, cliffs and hills. This has resulted due to dominance of physical weathering, the rolling down of these debris along slopes under the influence of gravity or brought down by the action of running water during the rainy season.

Residual soil unit is stretching in areas of moderate to gentle slopes. It is of azonal type and has undergone weathering for a prolonged period of time and developed a thick profile. It is formed from the parent rock and has finer particles now to support the growth of natural vegetation. This type of soil is found in the eastern part of the basin and extensively in the Tarapung Nadi tributary basin.

Hillslope deposits are loose and fine weathered materials found along the gentle to moderately sloping valley slopes. They are mainly noted at the pediment of the hills and plateau fringes within the Kaliani River Basin. They are dark, weathered soil though not very deep and support growth.

Terrace deposits are noticed along the middle course of the Kaliani River Basin. The materials are fine silt, cobbles and shingles, conglomerates and loosely binded calcite with pebbles. Since these terraces have formed due to downcutting

action of the channels, they exhibit the type of deposits found at each layer and the nature of the rocks with each level.

IV. RESULTS AND DISCUSSIONS

The terrain stability zones identified, demarcated and mapped have helped to identify the areas which are prone to denudation within the study area. The slope of the land, nature of underlying rock cover and the dominant agent of degradation are major factors noted here. The rugged and moderately inclined slope faces readily dispose of loose material and are exposed as bare rock faces. The intense action of weathering (both physical and chemical) lead to slow decay and removal of soluble minerals between the grains of the rocks, leading to disintegration .The loose fragmented pieces are removed by wind and running water. The denuded parts appear bare, with sparse vegetation cover and resistant rocks like granite, gneiss and some ferruginous sandstones jutting out. Figure 3 shows the terrain stability zones of the Kaliani River Basin.

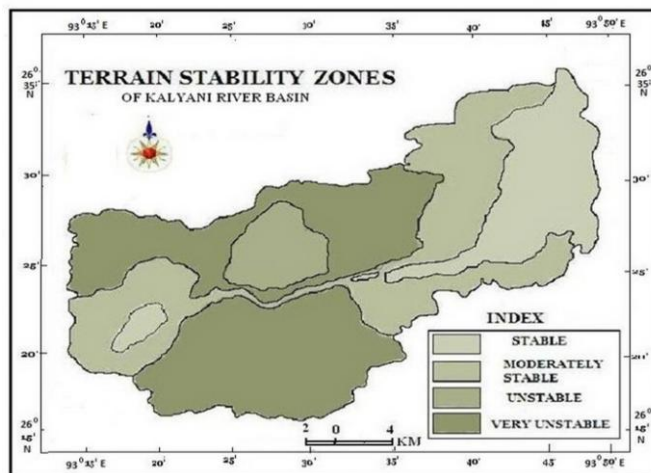


Fig. 3. The stability zones of the Kaliani River Basin

A description of the terrain stability zones of the Kaliani River Basin has been attempted below.

The very unstable zone occupies the central portion of the catchment covering about 40.83% of the total basin area. It is characterized by maximum drainage segments, hillslope deposits, rocks of low rock mass strength, maximum sheet wash and volcanic deposits and gneisses. The region has more numbers of jointed rocks and undergoes intensive weathering. Geomorphic processes operate nominally here and minimal rill and gully erosion take place.

The unstable zone covers the northern part of the catchment and amounts 16.67 % approximately of the total area. It has moderately steep slopes, landslides are common as the volcanic plug in this region has loose friable, less resistant rock, which slip down along slopes as they have minimal adhesion to their underlying beds.

The moderately stable zone occupies the far western and eastern side of the catchment covering about 30.64 % approximately of the basin area. This unit is chiefly characterized by rocks of high rock mass strength like quartzite rocks. Relief is moderate to high and there is scope for deposition of soil through moderate weathering processes. Mass movement is noted though in the form of mudflows.

The stable zone comprises the eastern part and the narrow zone along the mid course of the Kallani River Basin. It occupies 11.86 % of the total basin area. This area has rocks of very high rock mass strength and is relatively stable with flat terrain. It has a deep cover of regolith and agriculture on sustainable basis is done by the locals. The region has a number of abandoned river channels and oxbow lakes.

The main immediate causes of denudation in the study area are as follows:

- The tectonic and geologic background of the study area has significantly contributing to denudation by providing uplifting and resistant relief. The process of gradation and transportation as well as deposition of the sediments within the river basin is noted.
- Soil erosion, gullying and river bank failure is dominant due to removal of vegetation cover and trees, and mismanaged agricultural practices as shifting agriculture (Fig. 3).



Fig. 3 The rate of downcutting is faster than the parallel retreating of the banks due to denudation.

- Due to high velocity runoff at the sites of steep river banks, removal of top soil cover leads to rapid land degradation by inhibiting vegetation growth.

- The clearing of bamboo forests for supply to the Nagaon Paper Mill and cutting indigenous tree covers for supply to saw mills, plywood factories and veneer units have resulted in rapid deforestation leading to open areas prone to denudation.
- The growth of the tea industry has led to clearing away of large forested areas for plantations.
- For accessing coal and limestone illegally, indiscriminate clearing away of forested land in pockets has led to decline in forest resources.

V. CONCLUSIONS

Denudation in any open natural system brings down the level of relief that has been uplifted by tectonic upheavals. In a river system it operates chiefly upon the elevated portion of the landscape, producing sediments with the aid of weathering and they are transported downslope through erosional processes. According to Penck (1925,88), Chorley et al. (2001) in a stream system where the stream is cutting down to a given depth, the rate of denudation increases as erosional activity decreases. In this case the Kalyani River which is trying to attain its base level in tandem with the River Dhansiri to its east, the past upheavals have not altered its gradient. This is because the channel has adjusted itself and cut back into its channel bed with renewed force.

Denudation of the Kalyani River Basin can be termed as a whole as moderate as the rates of erosion are still high. The banks of the river are steep and denudation is slow as the downcutting action of the river is dominant. They cannot retreat parallel as proposed by Penck (1925, 88- 9), Chorley et al 2001, as yet and hence the river channel has not widened even at its confluence. The river maintains a narrow channel with denudation being more active upon the water divides of the river basin and the detrital matter swiftly removed by wind and flowing water.

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